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Feibert, Diana Cordes; Jacobsen, Peter

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MEASURING PROCESS PERFORMANCE WITHIN HEALTHCARE LOGISTICS - A DECISION TOOL FOR SELECTING TRACK AND TRACE TECHNOLOGIES

Diana Cordes Feibert, Technical University of Denmark
Peter Jacobsen, Technical University of Denmark

ABSTRACT

Monitoring tasks and ascertaining quality of work is difficult in a logistical healthcare process due to cleaning personnel being dispersed throughout the hospital. Performance measurement can support the organization in improving the efficiency and effectiveness of processes and in ensuring quality of work. Data validity is essential for enabling performance measurement, and selecting the right technologies is important to achieve this. A case study of the hospital cleaning process was conducted at a public Danish hospital to develop a framework for assessing technologies in healthcare logistics. A set of decision indicators was identified in the case study to assess technologies based on expected process performance. Two aspects of performance measurement were investigated for the hospital cleaning process: what to measure and how to measure it.

INTRODUCTION

Logistical processes are essential for a hospital to function and in providing services for patients. Improving the efficiency and effectiveness of healthcare processes not only economizes on resources but also provides supports in reaching organizational goals (Gleason & Barnum, 1982; Mentzer & Konrad, 1991). Measuring the efficiency and effectiveness of a process can motivate employees and induce learning in order to improve processes (Neely, Gregory, & Platts, 2005). In a healthcare logistics context, employees will often perform tasks in various parts of a hospital without close management control. The lack of control and the dispersion of employees make it difficult to assess individual and process performance. Thus, from a principal-agent point of view, there is a need to measure and monitor the process (Kathleen M. Eisenhardt, 1989; Melnyk, Stewart, & Swink, 2004). Technologies such as RFID, barcodes and portable job agents can capture data in a process and enable process measurement (Ferrer, Dew, & Apte, 2010; Sarac, Absi, & Dauzère-Pérès, 2010). When measuring several performance indicators, one technology may not fit all, and a range of different technologies may be needed to enable performance measurement. Selecting the appropriate technologies for capturing data is important to ensure data validity and enable performance measurement.

A hospital is a complex system where a network of organizational units interact to perform various processes (Kannampallil, Schauer, Cohen, & Patel, 2011; Plsek & Wilson, 2001). The level of complexity can be determined by the interrelatedness between parts of a system and the uniqueness of those relations (Kannampallil et al., 2011; Simon & Cilliers, 2005). The uniqueness of healthcare processes stems from the unpredictable hospital environment as the

course of treatment differs for each patient (Jarrett, 1998). The uniqueness of the hospital processes means that certain conditions are intrinsic to a hospital context. Furthermore, the important role of the patient in the outcome of health services differs from other industries with a more production oriented focus (Lillrank, Groop, & Venesmaa, 2011). Thus, the decision criteria that are valid in other industries may not apply in a hospital setting.

The decision criteria for assessing technologies to measure process performance within healthcare logistics are investigated in this paper. This study aims to develop a framework that serves as a decision support tool for logistics management within healthcare. The purpose of the tool is to assess technologies that enable performance measurement. The framework is developed by answering the following research question (RQ): How can decision indicators identified in a hospital cleaning case be used to assess technologies for measuring process performance in a logistical healthcare process?

A REVIEW OF THE LITERATURE

Literature within the field of healthcare logistics is reviewed to understand what healthcare logistics involves. The technologies used in healthcare logistics are then found in literature and the need for assessment methods is identified.

Understanding healthcare logistics

In one of the early definitions of logistics, the change in form and location of inventory was viewed as the main value-added process in materials logistics management (Bowersox, Carter, & Monczka, 1985). The term logistics has evolved over time from a narrow definition focusing on the reduction of inventories to a more broad definition (Cooper, Lambert, & Pagh, 1997). Several and more elaborate definitions of logistics have since been proposed. One of the widely used definitions of logistics is that of the Council of Supply Chain Management Professionals who defines logistics as ‘that part of the supply chain process that plans, implements, and controls the efficient flow and storage of goods, services, and related information from the point of origin to the point of consumption in order to meet customers’ requirements’ (Council of Supply Chain Management Professionals, 2015). Lummus and colleagues provide a similar definition of logistics as ‘planning, implementing and controlling efficient, effective flow and storage of goods and services from the beginning point of external origin to the company and from the company to the point of consumption for the purpose of conforming to customer requirements. Logistics is generally viewed as within one company, although it manages flows between the company and its suppliers and customers’ (Lummus, Krumwiede, & Vokurka, 2001). Controlling the flow of goods from point of origin to point of consumption in order to meet customer requirements seems to be recurring elements for the latter definitions. For this paper, logistics will be defined as by the Council of Supply Chain Management Professionals, and healthcare logistics is then logistics within a healthcare context.

The cost of providing healthcare has been rising and the pressure to provide healthcare services at lower costs has increased (OECD, 2013). The logistical costs in a hospital account for

more than 30% of hospital expenditure (Poulin, 2003). Reducing costs related to healthcare logistics therefore provides an opportunity for addressing the challenge of increasing healthcare costs. Studies have investigated how the logistical activities in a hospital are performed and the opportunities for improving processes to reduce costs by implementing improvement initiatives such as just-in-time systems (Aptel & Pourjalali, 2001; Jarrett, 1998, 2006; A. Kumar, Ozdamar, & Ning Zhang, 2008; S. Kumar, DeGroot, & Choe, 2008), innovation processes (Lee, Lee, & Schniederjans, 2011; Su, Gammelgaard, & Yang, 2011), Lean (Hicks, McGovern, Prior, & Smith, 2015; Joosten, Bongers, & Janssen, 2009; Kollberg, Dahlgaard, & Brehmer, 2007; Poksinska, 2010; Souza, 2009), TQM (Chen, Chen, Wu, & Lin, 2004; Chow-Chua & Goh, 2000; Pinna, Carrus, & Marras, 2015), Six Sigma (Jin, Switzer, & Agirbas, 2008; Lifvergren, Gremyr, Hellström, Chakhunashvili, & Bergman, 2010), and Business Process Reengineering (A. Kumar et al., 2008; A. Kumar & Rahman, 2014). These improvement initiatives are all process oriented. Healthcare logistics processes have been investigated to some extent in literature, including medical supply (A. Kumar et al., 2008), pharmaceutical supply (Mustaffa & Potter, 2009; Romero & Lefebvre, 2015), patient flow logistics (Kriegel, Jehle, Dieck, & Tuttle-weidinger, 2015; Lillrank et al., 2011; van Lent, Sanders, & van Harten, 2012; Villa, Barbieri, & Lega, 2008; Villa, Prenestini, & Giusepi, 2014), sample transports (Al-Riyami et al., 2014; Jørgensen, Jacobsen, & Poulsen, 2013), and bed logistics (Feibert & Jacobsen, 2015; Schmidt, Geisler, & Spreckelsen, 2013; Utley et al., 2003). However, other logistical processes exist in a hospital such as laundry management, waste management, catering, mail service, security, cleaning, and managing surgical tools (Aptel & Pourjalali, 2001; Granlund & Wiktorsson, 2013; Jørgensen, 2013; A. Kumar & Rahman, 2014; Pan & Pokharel, 2007). Many of these hospital logistics services will often be outsourced, especially cleaning, security and catering (Moschuris & Kondylis, 2006). The literature survey shows that several logistical healthcare processes have not been explored in literature. Patient flow logistics has been studied more extensively, whereas the study of other logistical healthcare processes is limited.

The process improvement methods mentioned above can reduce waste in healthcare processes. However, healthcare processes face variability in demand and should not only look to lean process strategies but also agile process strategies (Rahimnia & Moghadasian, 2010). Aronsson and colleagues therefore contend the need for a supply chain management perspective that utilizes lean to reduce waste, and uses agility to cope with uncertainty (Aronsson, Abrahamsson, & Spens, 2011). To provide a supply chain management perspective, a number of studies have focused on logistical processes for the entire supply chain (Aronsson et al., 2011; de Vries & Huijsman, 2011; A. Kumar et al., 2008; Lillrank et al., 2011).

The cost of supplying a hospital can be divided into the cost of supplied goods, administration, overhead, and logistics (Neumann, 2003). The cost of goods itself can be expensive, especially pharmaceutical products. The cost of supply can be reduced by negotiating the price of the product but also by procuring refurbished products (Ross & Jayaraman, 2009). Another way to reduce the cost of supply is by reducing stock levels through inventory management. Additionally, purchasing decisions will directly affect inventory levels (S. Kumar et al., 2008). One of the challenges in procurement and inventory management is handling

variability in demand, making it difficult to achieve low or no stock levels. By collaborating and sharing information in the supply chain, uncertainty in demand can be reduced, leading to improved customer service levels or reduced inventory levels. Collaborative solutions such as Planning, Forecasting and Replenishment (CPFR), JIT and VMI use information sharing through information systems to create transparent and visible demand patterns (Holweg, Disney, Holmström, & Småros, 2005). Studies have assessed different collaborative solutions for healthcare supply chains. Both VMI solutions and JIT solutions have been found suitable for healthcare logistics. E.g. Mustaffa and Potter assessed vendor managed inventory (VMI) and JIT for Malaysian hospitals and found that VMI was preferable due to poor infrastructure, the distance between clinics, and the high number of delivery points (Mustaffa & Potter, 2009). Others have found JIT to be a viable solution for hospitals (Jarrett, 1998; Pan & Pokharel, 2007). This paper focuses on process management rather than purchasing and inventory management.

Use and assessment of technologies in healthcare logistics

In addition to information systems, the use of track and trace technologies can also improve purchasing decisions and reduce costs by lowering inventory (S. Kumar et al., 2008). Thus, technologies can be a means to achieve more efficient processes (Hammer, 1990; Jimenez et al., 2012; C. A. Voss, 1988). Different types of technologies have been implemented in healthcare logistics; these technologies include RFID (Chan, Choi, & Hui, 2012; Ferrer et al., 2010; Fosso Wamba, Anand, & Carter, 2013; Gastaldi, Mangiaracina, Miragliotta, Perego, & Tumino, 2015; A. Kumar & Rahman, 2014; S. Kumar et al., 2008; Qu, Simpson, & Stanfield, 2011; Romero & Lefebvre, 2015; Wang, Chen, Ong, Liu, & Chuang, 2006; Yao, Chu, & Li, 2012), barcodes (S. Kumar et al., 2008; Romero & Lefebvre, 2015), mobile devices (Granlund & Wiktorsson, 2013; Siau & Shen, 2006), ERP-systems (Jenkins & Christenson, 2001; Stefanou & Revanoglou, 2006; Woodside, 2007), MRP-systems (Steinberg, Khumawala, & Scamell, 1982), CPFR (S. Kumar et al., 2008; Lin & Ho, 2014), EDI (Spinardi, Graham, & Williams, 1997; Woodside, 2007), pneumatic tube systems (Al-Riyami et al., 2014; Bakken, 2012; Granlund & Wiktorsson, 2013; Jørgensen et al., 2013), Automated Guided Vehicles (AGVs) (Bakken, 2012; Granlund & Wiktorsson, 2013; A. Kumar & Rahman, 2014; Landry & Philippe, 2004), robotics (Takahashi, Suzuki, Shitamoto, Moriguchi, & Yoshida, 2010), conveyor systems (A. Kumar & Rahman, 2014; Markin, 1994), and automated inventory systems (Bakken, 2012). Overall, the identified technologies can be divided into three groups: 1) track and trace technologies, 2) planning and forecasting technologies, and 3) transport technologies. The technologies considered in this paper are the track and trace technologies.

The technologies used in health logistics as identified in literature are mainly assessed by identifying the benefits of the technology, e.g. (Anand & Wamba, 2013; Ferrer et al., 2010; Gastaldi et al., 2015). Ferrer studied the benefits of RFID across several industries and identified four benefits that were valid for all cases in the study. Thus, some of the identified benefits are industry specific. Literature tends to focus on the evaluation of a single technology, e.g. (Fosso Wamba et al., 2013; Yao et al., 2012), although some studies evaluate two technologies, e.g.

(Chan et al., 2012; Romero & Lefebvre, 2015). This paper seeks to identify the decision criteria that are specific to healthcare logistics and that enable the assessment of several technologies.

Other decision criteria than the benefits of a technology may be relevant for assessing a technology. Healthcare logistics should not only be viewed as a means for achieving savings for logistical processes but also as having a more strategic role by supporting the clinical organization to achieve more productive clinical processes (Landry & Philippe, 2004). Decisions in healthcare logistics such as technology assessment should therefore not only be based on financial criteria but also strategic considerations. Furthermore, technologies will often be introduced to improve process performance (Hammer, 1990; Jimenez et al., 2012; C. Voss, Tsiriktsis, & Frohlich, 2002), thus expected process performance should influence the assessment of technologies (Gastaldi et al., 2015), in order to reflect the goals and strategy of the organization (Brewer & Speh, 2000). Due to the multidimensional nature of logistics, it is necessary to measure more than one performance indicator when measuring the performance of a logistical process (Chow, Heaver, & Henriksson, 1994). Thus technologies should be assessed based on several criteria, including benefits of a technology and expected performance.

Performance measurement can provide a platform for improving process performance (Neely et al., 2005). A principal-agent problem occurs when a) goals differ between the principal and agent and b) information and verification of behavior is difficult (Kathleen M. Eisenhardt, 1989). Performance measurement can provide information that reduces information asymmetry between the principal and the agent. Principal-agent theory is used in this study to assess how different technologies affect data validity in the data capturing process.

Multiple criteria decision methods can include criteria that are both quantitative and qualitative in nature (T. L. Saaty, 2004a). There are several multiple criteria decision methods that can be used to assess alternative scenarios. Health Technology Assessment (HTA) is a widely used assessment method within healthcare. However, HTA focuses on solving a health problem and on improving the quality of life (WHO, 2015). Therefore, the HTA is not relevant for assessing track and trace technologies in healthcare logistics, where the aim is to provide more efficient and effective logistical processes. A simple multiple decision criteria method is weighted factor analysis, which has been used for assessing technologies in healthcare logistics (Jørgensen, 2013). A more sophisticated method is Analytic Network Process (ANP), which allows for a quantitative comparison of different solutions based on individual judgment or measurement of identified decision criteria. A special case of ANP is the Analytic Hierarchy Process (AHP), where the decision criteria are independent of each other (T. L. Saaty, 2004a, 2004b; T. Saaty & Vargas, 2006). AHP has been used to assess logistics performance (Korpela & Tuominen, 1996) and to identify critical success factors for introducing CPFR in healthcare (Lin & Ho, 2014). This paper does not focus on a specific quantitative method, but provides a set of decision indicators to which the quantitative methods can be applied.

METHODOLOGY

In this section, the research objectives, research design, collection of data, data analysis, and research quality are described for the study.

Aims and objectives

The aim of this study is to develop a decision support tool based on an investigation of the overall RQ, which focuses on logistical healthcare processes. In this study, a hospital cleaning process will represent a logistical healthcare process. The overall RQ is answered through a set of sub questions (SQs) which all investigate the hospital cleaning process. The SQs will address different aspects of the decision indicators to be defined for the overall RQ. Management of the hospital logistics department in the case study hospital seeks to improve the performance of the hospital cleaning process, and technologies are a means to achieving this (Hammer, 1990; Jimenez et al., 2012; C. A. Voss, 1988). Which technology to choose will therefore depend on the expected performance of the process. The decision indicators for assessing technologies in healthcare logistics should reflect the performance indicators used to assess performance. Process performance consists of an efficiency and effectiveness aspect; effectiveness relates to reaching a goal, whereas efficiency relates to the economic use of resources (Gleason & Barnum, 1982; Mentzer & Konrad, 1991). Aiming to reach organizational goals will therefore improve process effectiveness and consequently process performance. Studies show that setting clear, specific and particularly challenging goals leads to increased performance. Thus, challenges and goals are closely related, and the more challenging a goal is, the higher the level of performance will be (Locke & Latham, 2002; VandeWalle, Cron, & Slocum Jr., 2001). Challenges and goals are therefore addressed in SQ1 because addressing challenges and setting goals will lead to improved process performance. Similarly, performance indicators are addressed in SQ2 because they reflect performance of a process. Lastly, risk factors affecting data validity are addressed in SQ3 to include the purpose of the technology in the decision process, i.e. to provide valid data. These risk factors relate to informational risks, e.g. capturing and use of data as well as access to key information (Cavinato, 2004), or system risks, e.g. information system breakdowns (Tummala & Schoenherr, 2011). The results from SQ1-SQ3 lead to SQ4 where the final decision indicators used for assessing technologies to measure process performance are identified. The SQs investigated in this study are as follows:

- SQ1: What are the challenges and management goals for a hospital cleaning process?*
- SQ2: How can performance indicators measure process performance of a hospital cleaning process to address challenges and help achieve management goals?*
- SQ3: What are the risk factors affecting data validity for technologies capturing performance data in the hospital cleaning process?*
- SQ4: Which decision indicators should be used to assess technologies capturing performance data in a hospital cleaning process?*

Research design and data collection

This study is a qualitative study within the field of operations management. A single case study design was chosen because it provides an in-depth understanding of a problem and is well suited for answering “how” questions (K. M. Eisenhardt, 1989; Yin, 1994). Furthermore, case studies are suitable for investigating research questions within the theoretical field of operations

management (McCutcheon & Meredith, 1993; C. Voss et al., 2002). The case study method has also been widely used within healthcare logistics, e.g. (Granlund & Wiktorsson, 2013; A. Kumar et al., 2008; Pan & Pokharel, 2007; Wang et al., 2006). The case study investigated in this paper is a study of the hospital cleaning process at a public Danish hospital. The hospital cleaning process has mostly been treated in literature to investigate the methods for cleaning as well as methods and indicators for assessing cleanliness (Al-Hamad & Maxwell, 2008; Dancer, 2004; Griffith, Cooper, Gilmore, Davies, & Lewis, 2000; White, Dancer, & Robertson, 2007). This paper takes a slightly different approach. The study investigates how the hospital cleaning case can be used to identify decision indicators for assessing technologies that capture performance data. Although cleaning at a hospital is not considered a traditional logistical process, it was identified in the literature review as a logistical process less treated in literature. The process contains some logistical elements. First, the service of cleaning is *distributed* across the hospital. Secondly, the technologies investigated are technologies commonly used within *supply chain management* and *logistics*, such as RFID and barcodes (Ramanathan, Ramanathan, & Ko, 2014).

The case study hospital is a public Danish hospital in the greater Copenhagen area with room for approximately 700 inpatients at a time. The hospital covers many medical areas but specializes in cancer treatments and also holds a large mother and child facility. Furthermore, the hospital treats almost 500,000 outpatients a year and has an emergency department that treats around 70,000 patients a year. The case study hospital was chosen because of 1) the accessibility to data and 2) the relatively large size of the hospital, which accentuates the challenge of overseeing a large number of cleaning personnel within an extensive area.

Data for the hospital cleaning case was collected over a five month period from October 2014 to February 2015 following a case study protocol. During the case study, 20 interviews were carried out, the cleaning process was observed, and several documents were collected. Interviews were carried out with managers and supervisors of the logistics and cleaning department at the primary case study hospital. Interview persons from another hospital were interviewed to get insight into how the hospital cleaning process was conducted elsewhere. Furthermore, managers from the central IT department for Danish healthcare and the central Strategy department for hospitals in the region were interviewed to learn about the more strategic aspects of technologies and about performance measurement. The interview persons were selected based on their involvement and knowledge about the hospital cleaning process or about data and performance measurement within the Danish healthcare system. Toward the end of the study, case study results were presented to management of hospital logistics at the primary hospital for respondent validation (Bryman, 2012; Yin, 1994). An overview of the interviews and observations for this case study can be found in Table 1.

The conducted interviews were semi-structured interviews that lasted between ½-1 hour depending on the questions that were covered. The interview questions discussed with the interview persons are listed in Table 2 and are linked to the SQs. The interviews were conducted based on more elaborate interview guides that included more questions.

Table 1 Overview of interviews		
<i>Organization</i>	<i>Roles of persons interviewed</i>	<i>Interviews / observations</i>
(A) Primary case hospital	Head of hospital logistics	2 interview
	Manager of Cleaning department	3 interviews
	2 supervisors in Cleaning department	2 interviews
	Planning coordinator for cleaning	2 interview
	OR logistical services coordinator	2 interviews
	2 head nurses (Urological and Medical departments)	2 interviews
	Hygiene nurse (Hygiene department)	1 interview
	Observation of cleaning process	1 observation
(B) Other hospital	Manager of Cleaning department	1 interview
	Lean consultant	1 interview
(C) Central Lean and Strategy unit for the hospital region	Lean consultant	1 interview
(D) Central IT department for Danish healthcare	2 heads of IT architecture	2 interviews
	IT platform project manager	1 interview

Table 2 The relation between main interview questions and research sub questions	
<i>SQs</i>	<i>Interview questions</i>
SQ1	What are the main challenges in the hospital cleaning process?
	What are the main goals for the hospital cleaning process?
SQ2	How could capturing data help solve challenges in the hospital cleaning process?
	How could measuring process performance help solve challenges in the cleaning process?
	What should potential performance indicators measure?
SQ3	How could technology help solve the challenges in the hospital cleaning process?
	Which technologies do you use in the hospital cleaning process?
	Which technologies have you considered to use in the hospital cleaning process?
	What are the risk factors that could affect data validity when capturing data?
SQ4	Which decision parameters would be relevant for assessing technologies to be implemented in the hospital cleaning process?

Analyzing data to investigate the research questions

Each SQ is addressed in turn to answer the overall RQ. For SQ1, challenges and management goals for the hospital cleaning process were identified by mapping and analyzing the hospital cleaning process. Furthermore, challenges and goals were identified through interviews and discussions with logistics management. In SQ2, performance indicators were developed together with management. The performance indicators were based on the strategy and goals of the organization (Brewer & Speh, 2000). In addition, challenges were included as a basis for the performance indicators because of the close relation between challenges and goals, i.e. overcoming challenges to reach goals (Locke & Latham, 2002; VandeWalle et al., 2001). SQ3 was then investigated to ensure data validity. The process of capturing performance data was analyzed to identify risk factors that affect data validity. The analysis was conducted by assessing the risk factors for different types of technologies. These technologies were identified based on literature and interviews in the case study and included the following: iBeacon, tablet, RFID, barcode, and a portable jobagent. Lastly, a set of decision indicators were identified in SQ4 based on findings from SQ1-SQ3. The identified decision indicators in SQ4 therefore relate to challenges and goals (SQ1), performance indicators (SQ2), and data validity (SQ3). The implications for management were then summarized based on the results.

Validity and reliability

A case study protocol was developed to plan and guide the research activities. The different strategies adopted for collecting data were interviews and observations, and data from several sources were gathered and analyzed. To validate the findings, respondent validation was carried out by interviewing key informants to ensure construct validity (Bryman, 2012; Denzin & Lincoln, 1994; Yin, 1994). To generalize the findings beyond a context within Danish healthcare logistics, a similar study should be conducted outside of Denmark. The case study does not aim to generalize universally but to find out under which conditions certain outcomes can be predicted (Yin, 1994). Lastly, the reliability of the findings was ensured through colleague review and triangulation (Miles, Huberman, & Saldaña, 2014).

SQ1: IDENTIFYING CHALLENGES AND GOALS

Challenges and goals for the hospital cleaning process are identified in this section. First, the hospital cleaning process is mapped, and each process step is then analyzed in turn to identify challenges and goals in the process. The current hospital cleaning process is fairly simple and can be seen in Figure 1.

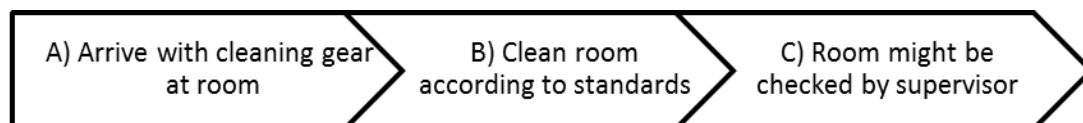


Figure 1 – simple mapping of the current hospital cleaning process

Step A: Arrive with cleaning gear at room

The first process step is the arrival of resources at the place to be cleaned. It is the responsibility of management in the Cleaning department that enough resources are available for the needed cleaning tasks, i.e. *security of supply*. Furthermore, the employees must have the right competences to perform the cleaning tasks satisfactory. One of the challenges experienced by the clinical departments was that the knowledge and quality of cleaning demonstrated by the cleaning personnel during the weekends did not live up to the same standards as on weekdays. This quality issue is related to *employee competences* and translates into *output quality* of the performed tasks.

Step B: Clean room according to standards

The cleaning department faces a huge communication and *information management* challenge. It is a challenge to convince people that a room has been cleaned and that it has been done satisfactory. As cleaning personnel will often clean the rooms when no one is in the room, people often mistakenly think that the room has not been cleaned. Only certain cleaning tasks are documented, and for these tasks, only end time and employee ID is registered. There is no *traceability* in the cleaning process and it is not registered nor communicated how much time was spent cleaning, who cleaned it or if it lived up to the necessary quality standards. For those tasks not documented, it is difficult to communicate and convince clinical staff, patients and visitors that the room has indeed been cleaned. Furthermore, the expectations of the clinical departments to the level of cleaning have not been aligned with the quality requirements for cleaning. I.e. even when the Cleaning department lives up to the required quality standards, they are still not satisfied with the result. There is a lack of understanding from the clinical departments as to what level of cleaning is required and what level of cleaning can be expected within a given timeframe. It is therefore difficult for the Cleaning department to communicate that they actually do a good job, and the work of the cleaning personnel is often not recognized.

One part of the communication challenge is to communicate what is already known, i.e. what the Cleaning department already documents. Another part of the challenge is to provide valid data for tasks that are currently not documented. Agreements have been made between the Cleaning department and the clinical departments about the cleaning tasks to be performed. However, it has been difficult to outline these contracts because it is not known how much time is actually spent per room. Part of this problem is that personnel often perform more tasks than written in the agreement. Creating transparency about which tasks have been performed and how much time is spent on them would make it easier to outline contracts and would also help create more trust in the Cleaning department. Creating transparency about tasks would enable better planning and coordination of resources and provide the necessary information for determining process performance. Furthermore, transparency would ensure that the Cleaning department allows enough time for the employee to perform the cleaning task.

Another challenge in the hospital cleaning process is that resources are hard pressed for time. This is partly due to the way resources are planned as only just enough time is scheduled

for the employees to clean the rooms. The schedule is based on best practice and past experiences, but no time studies have been carried out. In addition, the cleaning organization faces high sickness absenteeism and difficulties retaining staff, which adds pressure on available resources. The high sickness rates and the issue related to retaining staff can partly be explained by the *employee work conditions* and *employee motivation*. Cleaning is hard work and improving work conditions is in the interest of management and employees to ensure a viable solution for both. Tools, technologies and knowledge about correct ways to perform tasks can alleviate the employees. Another work condition concern is that of monitoring the employees, which could lead to some privacy issues (Chao, Yang, & Jen, 2007; Fisher & Monahan, 2008; Reyes, Li, & Visich, 2012) and the risk of micro management. This concern was expressed by the manager of the Cleaning department:

"I would not want to perform micro management and control the individual; I would prefer focusing on the human being and on leading people."

The work conditions together with the lack of recognition of employee efforts do not provide an environment that encourages employee motivation. The organization has subsequently experienced high rates of employee absence, which has added to the pressure on available resources. Management in hospital cleaning is therefore interested in alleviating resources by eliminating any *unnecessary processes*.

Step C: Check quality of work

The quality of cleaning is important for the hospital as a step to contain any infections and avoid infections from spreading throughout the hospital. One of the goals for the hospital cleaning process is therefore to ensure that the rooms are cleaned sufficiently to help avoid infections from spreading. Thus, the *impact on related processes*, in this case the patient care, is of high importance to the cleaning process.

Summary of identified challenges and goals for the hospital cleaning process

The findings relating to SQ1 have been summarized in Table 3, providing an overview of the challenges and goals in the hospital cleaning process. The identified challenges and goals have been bundled based on similarities. These bundles serve as decision indicators for assessing technologies in a healthcare logistics setting.

SQ2: DEFINING THE PERFORMANCE INDICATORS

Measuring process performance for the hospital cleaning process is an important issue for logistics management at a hospital. Cleaning personnel disperse into all parts of the hospital to clean their designated areas, and it is currently not possible to monitor and check the work of all employees. As the head of logistics pointed out in an interview:

“My main concern is that I let all these people [cleaning personnel] loose [in the hospital] and I don't know what they're doing all day... if they're doing what they're supposed to do and if what they are supposed to do is actually the right amount of work... measuring what people do should also be done to ensure they are not overworked and have enough time to perform their tasks.”

Providing information through performance measurement could create transparency about employee performance and the quality of their work (Neely et al., 2005). However, the statement by the head of logistics indicates that creating transparency about performance is not only for the benefit of management and the hospital but also for the employees.

Table 3
Challenges and goals bundled into decision indicators

<i>Decision indicators</i>	<i>Challenges</i>	<i>Goals</i>
Security of supply	Scarce resources and difficulties in retaining the resources they have.	Ensuring enough resources to perform cleaning tasks.
Output quality	Cleaning quality differs between weekdays, weekends, and seasons (cleaning quality). Valid data not available for performance indicators (data quality).	Ensuring quality of work (cleaning quality). Ensuring valid data (data quality).
Employee work conditions	Cleaning is hard work. Enough time should be allowed to perform tasks.	Avoiding micro management.
Competence match	Competences are not the same in weekends as on weekdays.	Ensuring same quality of work regardless the day of the week.
Information management	Lacking use of technologies to capture data. Challenges faced with coordinating and prioritizing resources and tasks across teams. Lacking overview of continuous progress in tasks performed. Being unable to show what has actually been done. There is a challenge in assessing and communicating performance, and in aligning expectations with clinical departments.	Ensuring enough time is allowed for employees to perform tasks according to cleaning standards. Being able to determine whether a process is efficient. Being able to verify and communicate which tasks have been performed and to what quality level.
Traceability	Not knowing where employees are and what they are doing.	Being able to assess individual performance.
Employee motivation	Cleaning is hard work and efforts are often not recognized. This has led to lack of motivation and high absenteeism.	Making the job physically easier for employees and ensuring that their efforts are recognized.
Unnecessary process	Resources are hard pressed for time and no unauthorized breaks are allowed. This issue is enhanced by high absenteeism.	Eliminating any unnecessary processes in order to alleviate hard pressed resources.
Impact on related processes	Hospital infections spreading in the hospital.	Provide high quality cleaning and avoid infections from spreading.

Performance indicators should reflect the strategy of the organization and help achieve organizational goals (Brewer & Speh, 2000). To align organizational behavior with strategic goals, central management covering all hospitals in the region had defined the following five performance aspects to be measured: (1) quality, (2) resources, (3) productivity, (4) satisfaction, and (5) service delivery. These aspects of performance measurement are based on the overall strategy of the hospital region and should be traceable down to the individual employee. Based on the five aspects to be measured, a set of performance indicators were developed together with management. These indicators can be seen in Table 4. The performance indicators have been bundled into decision indicators that are aligned with the decision indicators found for SQ1.

In measuring quality (1) of the hospital cleaning process, it is only possible to check the quality of a random sample of rooms. The random sample of rooms is checked according to two quality standards and the share of rooms that passes the quality standards is then used as a quality measure, i.e. *% rooms passed quality check*. Additionally, to provide some quality assurance for the rooms not checked, supporting performance measures were developed. Case study interviews showed that quality and time spent on cleaning are closely related. Software is used to estimate the amount of time needed to clean each room. These norm times are adjusted on a regular basis to best reflect the amount of time needed to clean a specific room. Planning of resources is based on these norm times and the aim of management has been to allocate just enough time for an employee to clean a room at a satisfactory level. Thus, it is estimated that all the allocated time should be used for cleaning the room in order to achieve a satisfactory result. Demonstrating that a certain amount of time has been spent in a room could therefore provide supporting evidence of the level of quality. The suggested performance indicator *norm time/time spent cleaning* is therefore both a productivity measure and a supporting quality measure.

Resources (2) are reflected in the performance indicators by measuring *% sick leave* and *#employees on leave*. As mentioned in the section identifying challenges and goals for the hospital cleaning process, one of the major challenges is that employee absenteeism is high for the department and that employees are hard pressed for time. Management is therefore interested in closely monitoring the availability of resources.

Productivity indicators (3) were developed to reflect how much time was spent on value-adding processes by measuring *norm time/time spent cleaning*. *Norm time/time spent cleaning* can also be viewed as value-added time. To measure the efficiency of the individual employee, *#planned cleanings/employee* was chosen as an indicator.

Satisfaction (4) was already assessed in a yearly report though a survey sent out to all departments in the hospital. This report was a qualitative study and not a quantitative measure as such, and management wished to keep it that way.

Finally, for service delivery (5), two indicators were selected. To make it easier to outline contracts with clinical departments and communicate about performed tasks, *% delivered of planned* was chosen as an indicator. *% delivered of planned* indicates how many of the promised tasks were actually finished. Another aspect of service delivery interesting to management was the *lead time* for acute tasks. Compared to the planned tasks, these tasks were time sensitive and timely delivery imperative.

Table 4 Performance indicators bundled into topics	
<i>Decision indicators</i>	<i>Performance indicators</i>
Output quality	% rooms passed quality check Norm time/time spent cleaning (supporting indicator) Experienced service report
Value-added time	Norm time/time spent cleaning (primary indicator)
Security of supply	# finished tasks / promised % delivered of planned
Lead time	Lead time
Unnecessary process	# planned cleanings / employee % sick leave # employees on leave
Traceability	All performance indicators should be traceable to the individual person.

SQ3: TECHNOLOGIES, RISK FACTORS, AND DATA VALIDITY

SQ3 investigates the process of capturing data within hospital cleaning. To measure the performance indicators identified in the previous section, it is necessary to capture different types of data in the process. In the following, each step of the data capturing process within hospital cleaning is analyzed to identify risk factors affecting data validity. The risk factors are summarized in Table 5 and bundled into decision indicators.

The process of capturing data within hospital cleaning

Technologies would be needed to enable measurement of the developed performance indicators for the hospital cleaning process. The alternative would be to manually register the data points in the process, which would be time consuming. Figure 2 shows an example of how data could be captured in the hospital cleaning process, in this case by registering start and end time of the cleaning process.

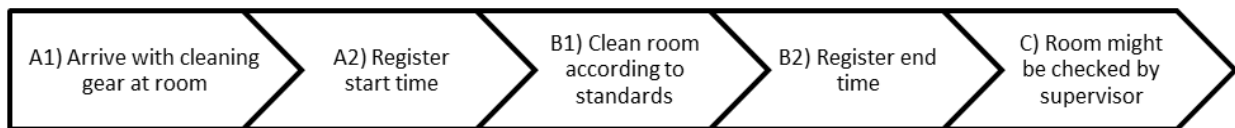


Figure 2 - mapping example of registering data in the hospital cleaning process

Five technologies were assessed for the hospital cleaning process for capturing performance data. These technologies were RFID, barcodes, tablets/apps, iBeacons, and portable jobagents. The hospital already uses some of these technologies such as barcodes, tablets and

portable jobagents, and the technology that the Cleaning department chooses could potentially be used by other departments. E.g. RFID could be used to track doctors, patients and medical equipment. Thus, taking into consideration that others may benefit from the technology suggests an element of *future proofing*. Future proofing means that the chosen technology is also likely to be used by the hospital in the future and that it will not become obsolete any time soon.

Step A: Arrive at the room and register start time

The first steps of the process would be for the employee to arrive at the room to be cleaned (step A1) and then register the starting time (step A2). This registration would be done electronically, but not necessarily automatically. For the RFID and iBeacon technologies, this registration would happen automatically. Data such as room number, time stamp, and personnel ID could be registered. However, for other technologies, some manual effort would be needed to register data. For barcodes, the employee would have to scan a barcode such as one on an ID card, which would then register room number, time stamp, and personnel ID. Lastly, using tablets and portable jobagents means that the employee would have to identify the task, i.e. room to be cleaned, on the device. Upon identification on the device, time stamp and personnel ID would be registered.

The solutions with tablets and jobagents differ from the other solutions in that the registration does not require or ascertain the presence of an employee in a given location at a given point in time. Thus, from an agency theory point of view, it is not possible to ascertain whether the employee was present at the location at the given point in time, which means there is information asymmetry. *Traceability* will therefore reduce information asymmetry. Furthermore, the registration requires an effort of the employee to actively make a registration. Risk of forgetting to register data means there is a risk that data validity will be impaired if data is not registered automatically. I.e. the *degree of automation* is important in ensuring data validity. In addition, if data is not registered automatically, it might not be registered in a consistent manner, which would also increase the risk of mistakes. If the employee has to actively make a registration, this may not happen at the same point in the process every time. However, if the registration is automated, the risk of mistakes would be reduced and consistency would be ensured. Therefore, the degree of automation is closely related to *risk of mistakes* and *consistency*. Conversely, a higher degree of automation also means that the ability to capture data is fully dependent on the technology and that any *downtime and maintenance* may disrupt data capturing and thereby affect data validity. Lastly, for the technology to capture data, the employees must be able to use the technology, i.e. the technology should be *easy to use*, and the employees should possess the necessary *competences*.

The employee may not see it as in his or her interest to measure performance, especially personal performance. The goals of the employee may therefore differ from the goals of management. Viewing the registration task from an agency theory perspective; if the goals of management are not the same as those of the employee, and if it is difficult to obtain information about the employee's behavior, an agency problem occurs. Unless there is a *motivation for the employee* to make the registration, there is a risk that the employee may neglect or forget to do

so. It is important to note that monitoring individual employee performance will not only enable management to address poor performance but also to recognize good performance.

Step B: Clean the room and register end time

For step B2, the same risks affect data validity as identified for registering start time in step A2. Only step B1 will therefore be analyzed in the following. One of the challenges mentioned earlier is the differing level of quality between weekends and weekdays. The cleaning personnel during the weekends does not include experienced employees. Weekend personnel is often be people not working full time within the cleaning field. The less experienced employees are therefore not as knowledgeable and skilled as the more experienced employees. This lack of knowledge and skill has led to quality issues during the weekends. One way of addressing this challenge is to supply the employee with the correct knowledge when needed, thus helping the employees gain the needed *competences*. This could be done by providing videos and illustrations of how a certain task should be performed, e.g. using iBeacons or tablets.

Step C: Check quality of work

In the hospital cleaning case, a number of randomly selected rooms would be checked by a supervisor. The supervisor would follow a check list to assess the room according to two Danish quality standards (INSTA 800 and DS2451-10). The assessment would be noted on a physical template and later typed into a spreadsheet on the office computer. The extra process in documenting and re-documenting data is essentially an *unnecessary process* that increases the *risk of mistakes* and puts data validity at risk. Furthermore, the extra step also means there may be a shift in who performs the process, i.e. a *competence shift*.

Table 5	
Summary of identified risk factors affecting data validity	
<i>Decision indicators</i>	<i>Description of risk factors identified in the process analysis</i>
Future proofing	Ensuring that the technological solution capturing data will persist in the hospital to provide valid data in the future.
Traceability	Ascertaining time and location of the employee that performed a task is necessary to enable to assure that the employee had been at the location.
Degree of automation	Automating the process of registering data reduces the risk of mistakes in the way data is captured. It also ensures that data is captured in the same way and prevents employees from neglecting or forgetting data registration.
Risk of mistakes	Degree of automation is closely related to the risk of mistakes in data capturing. Incorrect registrations lead to incorrect and invalid data.
Consistency	Degree of automation and a reduced risk of mistakes lead to higher consistency in data. Inconsistency in data renders data incomparable.

Table 5 (continued) Summary of identified risk factors affecting data validity	
<i>Decision indicators</i>	<i>Description of risk factors identified in the process analysis</i>
Downtime and maintenance	Capturing data electronically means that data registration is dependent on the technology capturing the data. If the technology is temporarily not functioning or undergoing maintenance, data will not be captured.
Features and ease of use	If data is not captured automatically, one of the pre-requisites for enabling data registration is that employees are able to operate the technology. Ease of use makes it more likely that employees can operate the technology.
Competence match	Together with ease of use, ensuring that employees have the right competences will increase the likelihood of employees correctly operating the technology.
Employee motivation	Ensuring ease of use and the right competences are pre-requisites for enabling the use of technologies that are not automated. The next challenge is to ensure that the employee is then motivated to actively register data.
Unnecessary process	Unnecessary processes such as double entry of data increases the risk of incorrect data registration from one registration to another.
Competence shift	If double entry of data is handed over from one employee to another, the risk of incorrect data registration increases due to the risk of miscommunication.

SQ4: DEFINING THE DECISION INDICATORS

Defining decision indicators based on the case study analyses

As a result of the analyses conducted for SQ1-3, 18 decision indicators (Table 6) have been identified based on the hospital cleaning case. The purpose of the decision indicators in the framework is to enable assessment of alternative solutions for a logistical healthcare process.

To make the list of indicators more coherent and transparent, the 18 decision indicators were structured into logical categories. Commonalities were identified between decision indicators, and the decision indicators were grouped into four categories: Logistics, Technology, Procedure and Structure. Logistics refers to logistical activities as defined in the literature review. Technology refers to the track and trace technologies as found in the literature and in discussions with management in the case study. Procedure refers to the formalized processes in healthcare logistics, e.g. standard operating procedures. Finally, Structure refers to the organizational structure in a healthcare setting. The 18 decision indicators structured into the four categories form the developed decision framework in this case study. The framework is illustrated in Figure 3.

Table 6 Overview of identified decision indicators and the SQs they were identified for			
<i>Decision indicators</i>	<i>SQ1: Challenges/goals</i>	<i>SQ2: Performance</i>	<i>SQ3: Risks</i>
Security of supply	Challenges and goals		
Output quality	Challenges and goals	Performance indicators	
Competence match	Challenges and goals		Risk factors
Information management	Challenges and goals		
Traceability	Challenges and goals	Performance indicators	Risk factors
Employee work conditions	Challenges and goals		
Employee motivation	Challenges and goals		Risk factors
Unnecessary process	Challenges and goals	Performance indicators	Risk factors
Impact on related processes	Challenges and goals		
Value-added time		Performance indicators	
Lead time		Performance indicators	
Future proofing			Risk factors
Degree of automation			Risk factors
Risk of mistakes			Risk factors
Consistency			Risk factors
Downtime & maintenance			Risk factors
Features and ease of use			Risk factors
Competence shifts			Risk factors

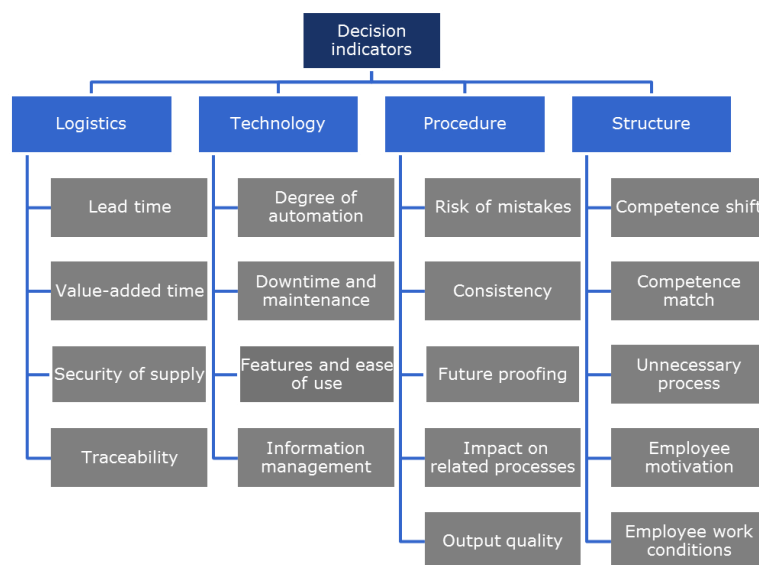


Figure 3 - Decision indicators for assessing technologies in healthcare logistics

Implications for management when assessing track and trace technologies

The implications for management of the results in this paper are presented in the following. A list of decision steps is proposed for selecting track and trace technologies to measure performance indicators within healthcare logistics. In the section analyzing SQ1, a list of challenges and goals were identified. Subsequently, a set of performance indicators were developed in SQ2. This paper considered the selection of technologies to measure these performance indicators. The combination of technology and data point to be measured creates a certain level of data validity, i.e. some technologies produce more valid data than others. In the investigation of SQ3, the risk factors affecting data validity were identified.

The financial aspect of selecting a technology is not covered by the 18 identified decision indicators identified in this paper. The main part of the Danish healthcare system is public, and funds are limited. This means that funding for logistical investments is often scarce as clinical investments are prioritized. Most organizations would not invest a large amount of money without calculating a business case, and the financial aspect of investing in technologies should therefore be considered alongside the identified decision indicators in the framework. In the process of selecting a new technology to invest in, the organization will have to secure the funds for the investment. Financial considerations could have practical implications for the choice of performance indicators and track and trace technologies. The benefits of the investment should outweigh the costs, and one of the benefits is the amount of data that will be provided by the technology. A certain number of data registrations above a level of some critical mass would therefore be a prerequisite for a profitable business case. Another financial aspect to consider is that one technology may not fit all. Thus, it may be necessary to invest in more than one technology or reduce the number of indicators to be measured. Although performance measures should be governed by the overall strategy of the organization (Brewer & Speh, 2000), the economically feasible technologies may not enable measurement of the preferred performance indicators. Steps should therefore be taken to accommodate any financial limitations. Based on the analysis presented in this section, the following decision steps are proposed for selecting technologies to measure process performance in healthcare logistics:

1. Select performance indicators based on goals, challenges, and strategy
2. Ascertain critical mass for data registration
3. Compare the 18 decision indicators for each of the potential technological solutions
4. Assess data validity for data-technology combinations based on the identified risk factors
5. Compare data validity with the cost of investment in technology
6. Determine feasible technological solutions from a financial perspective
7. Adjust performance indicators if necessary

The third decision step comparing the 18 decision indicators is one of the most extensive steps in the decision process. The comparison could be done qualitatively or quantitatively by using quantitative methods such as AHP or ANP.

DISCUSSION

Most of the literature on assessing technologies in a logistics setting tends to focus on the benefits of a specific technology, e.g. (Anand & Wamba, 2013; Yao et al., 2012). Some of the benefits identified in literature are generic across industries while others are specific to a particular industry (Ferrer et al., 2010). The developed framework focuses on decision indicators specific to a healthcare logistics context. In addition, the framework proposed in this study is suitable for assessing different types of track and trace technologies based on a set of decision indicators. The decision indicators can be evaluated for each technological solution and assesses the solution from a process performance perspective. Thus, the decision indicators in the framework do not only take the benefits of the specific technology into account, but provides a more context specific decision support tool. The context specificity is not only provided by assuming a process perspective, but also by considering effects outside of the process such as *impact on related processes*. Thus, a systems perspective is assumed, providing a more holistic view of the hospital. In addition, the type of hospital and the financial situation of the hospital may influence preferences of management. These preferences can then be expressed in the decision framework by letting management evaluate each decision indicator.

Some of the decision indicators resemble the benefits of technology adoption found in literature. E.g. Ferrer also identified automation as a benefit / decision criterion (Ferrer et al., 2010). The benefits identified by Ferrer relate to operations strategy objectives and are thus limited to the operations side of the hospital. Although the logistical processes considered in this paper are operations oriented, the decision criteria need not be limited to this. The strategy and organization of the hospital as a whole, especially the clinical departments, should also be taken into consideration (Landry & Philippe, 2004).

The main RQ was answered through four underlying SQs, which were each answered through three different analyses. Furthermore, implications for management were summarized in 7 decision steps proposed for assessing technologies in healthcare logistics. Findings in this paper are limited to a healthcare logistics context and should be validated for other contexts and settings outside of Denmark. The literature review revealed a lack of literature investigating specific healthcare logistics processes. This study is limited to a single case study of the hospital cleaning process, and similar studies of other healthcare logistics processes should be conducted. Based on the literature review, a gap in technology assessment for logistical healthcare was identified, and was subsequently investigated in this study. The developed framework showed similarities to existing literature while at the same time contributing with new knowledge on technology assessment.

CONCLUDING REMARKS

The framework proposed in this study has provided a set of decision indicators for assessing different types of track and trace technologies. The identified decision indicators were identified based on 1) challenges and goals, 2) performance indicators, and 3) risk factors affecting data validity. In addition to the decision indicators provided in this study, each of the

three aspects are interesting in their own right and can be used separately. E.g. to identify main challenges and goals of a process for process improvement purposes, developing performance indicators for a process improvement initiative, and lastly assessing data validity for different technologies. The main challenges identified in the case study were related to information management. The challenge of information management included creating transparency about which tasks had been conducted as well as the performance on quality and productivity. Being able to measure performance indicators would support better communication to the clinical staff, patients, and visitors. A set of performance indicators was proposed to enable communication of performance and to ensure that the cleaning tasks had been performed, and that they had been done satisfactory. To ensure quality of cleaning, productivity measures were developed to support the quality measures. This is to ensure that cleaning personnel has spent enough time in the room to clean it at a satisfactory level. This measure is especially important for rooms that have not been quality checked. Finally, risk factors affecting data validity were identified. The main risk factors relate to traceability, degree of automation, features and ease of use, and employee motivation. The technology used to capture data in the process will affect data validity, and data validity can be assessed for each technology by evaluating the identified risk factors. Furthermore, the feasible choice of performance indicators may be affected by the choice of technology.

This paper contributes with a set of decision indicators for assessing track and trace technologies in a healthcare logistics setting. The decision indicators form a framework that serves as a decision support tool for management in healthcare logistics. The framework is structured around four constructs: Logistics, Technology, Procedure, and Structure. In practice, the framework can be used either qualitatively by comparing each decision indicator for different scenarios and/or by applying a quantitative method such as AHP or ANP.

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